TABLE 8-4: REMEDIATION GOALS FOR RADIOLOGICALLY IMPACTED SOIL, STRUCTURES, AND GROUNDWATER

Parcel B Amended Record of Decision, Hunters Point Shipyard, San Francisco, California

Remediation Goals for Radionuclides

	Surfaces ($dpm/100cm^2$)		Soil[c] (pCi/g)		Water[e] (pCi/L)
Radionuclide	**Equipment, Waste[a]**	**Structures[b]**	**Construction Worker**	**Residential[g]**	**Equipment, Waste[a]**
Cesium-137	5,000	5,000	0.113	0.113	119
Cobalt-60	5,000	5,000	0.0602	0.0361	100
Plutonium-239	100	100	14.0	2.59	15
Radium-226	100	100	1.0[d]	1.0[d]	5.0[f]
Strontium-90	1,000	1,000	10.8	0.331	8.0

Notes:

a Based on "AEC Regulatory Guide 1.86" (1974). Goals for removable surface activity are 20 percent of these values

b Goals are based on 25 millirem per year (EPA does not believe this NRC regulation is protective of human health and the environment, and the HPS cleanup goals are more protective. This regulation is an ARAR only for radiologically impacted sites that are undergoing TCRAs and any additional remedial action required for those sites. It is not an ARAR for radiologically impacted portions of IR Sites 7 and 18 that will be transferred with engineering and institutional controls for radiological contaminants.)

c EPA PRGs for two future use scenarios

d Goal is 1 pCi/g above background per agreement with EPA

e Release criteria for water were derived from "Radionuclides Notice of Data Availability Technical Document" (EPA 2000) by comparing the limits from two criteria and using the most conservative value.

f Goal is for total radium concentration

g Also applies to scanned surface soil at IR Sites 7 and 18

AEC	Atomic Energy Commission	IR	Installation Restoration
ARAR	Applicable or relevant and appropriate requirement	NRC	Nuclear Regulatory Commission
cm^2	square centimeter	pCi/g	picocurie per gram
dpm	disintegration per minute	pCi/L	picocurie per liter
EPA	U.S. Environmental Protection Agency	PRG	Preliminary remediation goal
HPS	Hunters Point Shipyard	TCRA	Time-critical removal action

<u>Source of Goals</u>:

EPA. 2000. "Radionuclides Notice of Data Availability Technical Support Document." Targeting and Analysis Branch, Standards and Risk Management Division, Office of Groundwater and Drinking Water. March.

Navy. 2006. "Final Basewide Radiological Removal Action, Action Memorandum, Revision 2006. Hunters Point Shipyard, San Francisco, California." April 21, 2006.

Exposure Scenario	COCs in Groundwater, B-Aquifer[1]	
Residential	1,4-Dichlorobenzene; Antimony Arsenic; Benzene; Chloroethane	Manganese; Pentachlorophenol Thallium; Trichloroethene

Note:

1 COCs in the B-aquifer were identified based on evaluation of risks using a combination of A- and B-aquifer data, when available, to account for potential hydraulic communication in some areas of Parcel B.

7.1.5.3 Radiological Dose and Risk

Exposure to radiation at each radiologically impacted site was modeled using RESRAD for former building sites and open land areas; these risk calculations are based only on surface characterization and not on subsurface data. Exposure to radiation at radiologically impacted structures was modeled using RESRAD-BUILD. Table 7-3 presents the results of this evaluation. Table 7-1 summarizes the risk by redevelopment block. The release limits for each radionuclide of concern were used in the RESRAD and RESRAD-BUILD modeling. However, the actual risk and dose will be calculated using the results of the final status surveys and these actual doses will be lower than the release limits.

^{226}Ra is the only naturally occurring radionuclide of concern at Parcel B. ^{137}Cs and ^{90}Sr may be present in trace quantities because of fallout from nuclear weapons testing. The radiological dose and risk modeling considered the background concentration for radionuclides of concern other than ^{226}Ra to be 0 picocuries per gram (pCi/g). The ^{226}Ra background concentration was assumed to be the measured background level of 0.5 pCi/g.

The background concentrations of radionuclides of concern were assumed to be 0 disintegrations per minute (dpm) per 100 square centimeters for surfaces to model total risk from radiologically impacted buildings. This assumption was made because none of the radionuclides of concern are found in building materials, except for ^{226}Ra which can be found in earthen materials (such as cement and ceramic tile).

Appendix A of the TMSRA radiological addendum (TtEC 2008a) discusses the input parameters and modeling results for the radiological dose and risk for each radiologically impacted site.

7.2 SCREENING-LEVEL ECOLOGICAL RISK ASSESSMENT

The majority of Parcel B, approximately 75 percent, is covered by pavement and buildings. With little open space for flora and fauna, Parcel B is considered to have insignificant habitat value and poses an insignificant risk to terrestrial ecological receptors. Exposure pathways to terrestrial species are incomplete because of a lack of habitat and the predominance of paved areas in Parcel B (PRC 1996b). However, potential ecological risk to receptors near the shoreline was not previously evaluated. Therefore, a SLERA was conducted to evaluate potential ecological risks from exposure to shoreline sediment. Appendix B of the TMSRA (ChaduxTt 2007) presents the details of the SLERA.

Table 5. Remediation Goals for Radionuclides
Record of Decision for Parcel C, Hunters Point Shipyard, San Francisco, California

Radionuclide	Surfaces ($dpm/100\ cm^2$)		Soil (pCi/g)[d]	Water (pCi/L)
	Equipment and Waste[a]	Structures[b]		
Cesium-137	5,000	5,000	0.113	119
Cobalt-60	5,000	5,000	0.0361	100
Plutonium-239	100	100	2.59	15
Radium-226	100	100	1[c]	5
Strontium-90	1,000	1,000	0.331	8
Thorium-232	1,000	36.5	1.69	15

Notes: Unless otherwise stated, the radiological remediation goals in this table are based on total activity per sample including the background.

a Limits for removable surface activity are 20 percent of these values.

b Remediation goals are consistent with those issued in the Radiological TCRA Action Memorandum. Remediation goals meet the 25 mrem/yr residual dose level consistent with 10 CFR Section 20.1402. Furthermore, for most radionuclides of concern, goals meet the 15 mrem/yr residual dose level for most radionuclides of concern, consistent with the 1997 EPA OSWER Directive (OSWER No. 9200.4-18). An exception is the goal for thorium-232 which, because of technical limitations in the detection limit, corresponds to a dose of 25 mrem/yr.

c Goal is 1 pCi/g above background per agreement with EPA.

d All radiologically impacted soils will be remediated according to Residential Remediation Goals.

CFR *Code of Federal Regulations*
$dpm/100cm^2$ Disintegration per minute per one hundred square centimeters
EPA U.S. Environmental Protection Agency
millirem One thousandth of a rem (10^{-3})
mrem/yr Millirems per year
OSWER Office of Solid Waste and Emergency Response
pCi/g Picocuries per gram
pCi/L Picocuries per liter
TCRA Time-Critical Removal Action

For nonradiological COCs, exposure scenario-specific risk-based concentrations (RBC) were calculated based on a target excess cancer risk level of 1×10^{-6} and target noncancer HI of 1, consistent with the exposure pathways and assumptions used in the HHRA to assess risks. The selection of these target risk levels is based on agreements with the BCT and the Conveyance Agreement for Parcel C. Remediation goals for nonradiological COCs were selected based on a comparison of the COC-specific RBC, the laboratory practical quantitation limit (PQL) based on standard EPA analytical methods, the HPAL (ubiquitous metals in soil only), and the drinking water ARARs (RU-C5 B-aquifer groundwater only).

For ubiquitous metals in soil, the RBC was also compared with the HPAL; if the HPAL exceeded the RBC, the HPAL was selected as the remediation goal. For organic COCs in the RU-C5 B-aquifer, the chemical-specific ARAR was used as the RAO, if established. In all other cases, the RBC was selected as the remediation goal, unless the RBC was below the laboratory PQL. The RBC is calculated based on target risk and hazard levels associated with

Table 8. Remediation Goals for Radionuclides *(continued)*

Radionuclide	Soil and Sediment[a] (pCi/g)[a]		Surfaces	
	Industrial Worker	Residential	Equipment, Waste (dpm/100 cm^2)	Structures (dpm/100 cm^2)
Strontium-90	10.8	0.331	1,000	1,000
Uranium-235	0.398	0.195	5,000	488

Notes: The basis (risk-based) for the RGs is presented in Section 3 of the radiological addendum to the FS Report.

a = RGs for two future use scenarios; however, the residential RGs will apply in all Parcel E areas. These more conservative RGs will enhance the protectiveness of the remedial action for Parcel E, particularly as it relates to future property transfer and the potential need to apply institutional controls for radionuclides.

b = RG for Cobalt-60 was revised to support efficient laboratory gamma spectroscopy analysis of soil samples. This revised RG maintains morbidity risks within the U.S. Environmental Protection Agency-defined acceptable range and permits an exposure level that does not increase the risk of cancer from a potential exposure to Cobalt-60.

c = Objective is 1 pCi/g above background per agreement with U.S. Environmental Protection Agency (established in "Final Basewide Radiological Removal Action, Action Memorandum – Revision 2006, Hunters Point Shipyard, San Francisco, California," dated April 21, 2006). The Radium-226 background level for surface soil is 0.633 pCi/g. The Radium-226 background level for storm drain and sewer lines is 0.485 pCi/g.

dpm/100 cm^2 = disintegrations per minute per 100 square centimeters

pCi/g = picocurie per gram

RG = remediation goal

The RAO for radiologically impacted media outside of IR-02 and IR-03 would be satisfied through actions involving removal. The RAO for radiologically impacted media within IR-02 and IR-03 would be satisfied through actions involving a combination of removal, containment, monitoring/maintenance, and ICs. The RAO for radiologically impacted media does not pertain to groundwater because, as described in Section 2.3.4, previous investigations have not identified radionuclides in groundwater at activity levels that warrant remedial action. However, the selected remedy at IR-02 and IR-03 includes future monitoring to demonstrate, consistent with the findings of previous radiological investigations, that radionuclides are not present in groundwater at activity levels that are both statistically significant and pose an unacceptable risk to human health and the environment. The determination of statistical significance will be made in accordance with the substantive provisions of Title 22 California Code of Regulations § 66264.98(i). The duration of the groundwater monitoring for radionuclides will be determined in accordance with Title 22 California Code of Regulations § 66264.90(c). Section 2.9.2 provides further information on the actions required to satisfy the RAOs for radiologically impacted media.

Table 5 lists the remediation goals for COCs and COECs in soil. Table 6 lists the remediation goals for COCs and COECs in shoreline sediment. Table 7 lists the remediation goals for COCs in groundwater. Table 8 the remediation goals for ROCs in radiologically impacted media. Remediation goals were not developed for COECs in groundwater because, except for total TPH, the water quality criteria referenced in the groundwater and NAPL RAOs are based on standards for aquatic wildlife in San Francisco Bay, apply to surface water at the interface of A-aquifer groundwater, and do not apply to in-situ A-aquifer groundwater at Parcel E. Plume-specific **trigger levels**(30)[11] will be used as groundwater monitoring criteria

[11] Trigger levels were developed (in the FS Report for Parcel E) for specific groundwater plumes by applying attenuation factors to pertinent surface water quality criteria (as identified in pertinent surface water ARARs and, for select metals, adjusted for ambient levels). The attenuation factors vary based on several parameters (most notably, width of the contaminant plume and distance to the bay) and provide a conservative estimate of the advection and dispersion that reduces chemical concentrations as groundwater moves from an inland location to San Francisco Bay. Further information on the development of trigger levels is provided in the hyperlinked reference document (Attachment 2).

Table 6. Remediation Goals for Radionuclides in Soil and Sediment

Radionuclide of Concern	Exposure Scenario	
	Outdoor Worker (pCi/g)	Resident[a] (pCi/g)
Cesium-137	0.113	0.113
Cobalt-60	0.252[b]	0.252[b]
Radium-226	1.0[c]	1.0[c]
Strontium-90	10.8	0.331

Notes: The basis (risk-based) for the remediation goals is presented in Sections 7 and 9 of the radiological addendum.

a = Residential use is not planned for Parcel E-2, but residential goals are proposed as an additional level of protection.

b = Remediation goal for cobalt-60 was revised to support efficient laboratory gamma spectroscopy analysis of soil samples. This revised remediation goal maintains morbidity risks within the EPA-defined acceptable range and permits an exposure level that does not increase the risk of cancer from a potential exposure to cobalt-60.

c = Remediation goal is 1 pCi/g above background per agreement with EPA (established in "Final Basewide Radiological Removal Action, Action Memorandum – Revision 2006, Hunters Point Shipyard, San Francisco, California," dated April 21, 2006), and is consistent with the radiological-related remedies selected in the RODs for Parcels B, G, and D-1 and UC-1. The radium-226 background level for surface soil is 0.633 pCi/g. The radium-226 background level for storm drain and sewer lines is 0.485 pCi/g. The background levels for radium-226 may be reevaluated in the Parcel E-2 RD and are subject to regulatory agency approval.

EPA = U.S. Environmental Protection Agency

pCi/g = picocuries per gram

RD = remedial design

RODs = Records of Decision

- Sandblast waste from the decontamination of OPERATION CROSSROADS ships was disposed of at sea until December 1946. After that time, the Navy directed that biological growth (the most significant areas of radiologic contamination) be removed manually and disposed of at sea before general sandblasting. The sandblast waste was then deemed acceptable for unregulated disposal and may have been buried at HPS, including at the Landfill Area (as well as elsewhere at IR Site 01/21).
- The USS INDEPENDENCE, the last OPERATION CROSSROADS ship at HPS, was used for experimentation until it was loaded with radiologic waste and sunk at sea in January 1951.
- Aerial photographs indicate that most of the Landfill Area was filled after 1955 (see Figures 1-6 through 1-9 in the RI/FS Report) and therefore after decontamination of OPERATION CROSSROADS ships had ceased (in 1951).
- From 1952 to 1955, two ex-Liberty ships were modified to support the study of the effects of atomic weapons. The ships were used to provide support for research during weapons tests in the Pacific through the early 1960s. Following participation in the test, the ships would return to HPS for decontamination. For these ships, the HRA indicates that "sandblast material was to be controlled (collected and drummed as radioactive waste) during removal of 'hot spots' (not further defined). Once the hot spots were removed, the remaining sand could be disposed of in the Bay."
- The HRA further indicates that "by 1956, a new directive regarding the disposal of liquids and sandblast material into the Bay stated that decontamination was to be '*witnessed by shipyard personnel to prevent runoff of contaminated liquids or dumping of contaminated wastes into bay waters at dockside. All contaminated wastes shall be disposed of in accordance with existing regulations.*'" The disposal regulations are not defined in the HRA or supporting documents, so it not known whether radiologically contaminated sandblast waste was disposed at the Landfill Area (or elsewhere at IR Site 01/21) after 1955. The HRA did not identify records indicating the number of ships potentially decontaminated at HPS after 1955; only three atomic tests were performed in the Pacific Ocean from 1956 to 1962, at which point the United States ceased atmospheric atomic testing (Radiochemistry Society, 2011).

This information suggests that, while sandblast waste was probably disposed of at the Landfill Area (as well as elsewhere at IR Site 01/21), the sandblast waste with the highest levels of radioactivity from atomic testing was likely controlled and not disposed of at Parcel E-2.

Because of the potential for sandblast waste to contain radiological contamination, the Navy has implemented a field protocol to sample and analyze any sandblast waste encountered during intrusive activities at HPS. The protocol involves an initial analysis for ^{137}Cs and, if ^{137}Cs is identified, the waste is analyzed for ^{90}Sr. If both ^{137}Cs and ^{90}Sr are identified, then the waste is analyzed for alpha emitters (most notably, plutonium-239 and ^{235}U). This protocol was followed for sandblast waste found during previous removal actions at Parcels E and E-2 and neither ^{137}Cs nor ^{90}Sr were identified in sandblast waste at activity levels exceeding background levels. This finding is consistent with the operational history of the shipyard in that throughout shipyard operations (early 1940s through the early 1970s), abrasive sandblast material was commonly used to clean ships not associated with radiological operations.

line. Approximately 900 areas in Parcel E and E-2 were noted during the survey that exceeded twice the background gamma radiation levels; the highest measurements were identified in the area known as the "metal reef" within Parcel E. Samples collected from those locations identified ^{226}Ra as the contaminant.

3.1.6. Phase V Radiological Investigation (2002 to 2003)

The Phase V radiological investigation began in January 2002 prior to issuance of the HRA. The purpose was to support the release of buildings or areas that had been identified as areas where radioactive materials had been used or areas where previous removal actions to remove known contamination had occurred. The Phase V investigation of what is now Parcel E-2 was performed in 2002 and 2003, and the results were not available for inclusion in the HPS HRA (NAVSEA, 2004); therefore, the Phase V investigation results are presented for the first time in this radiological addendum. The scoping survey was of the surface only and was designed to meet the requirements of a Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM) Class 1 Final Status Survey if contamination was not found (U.S. Department of Defense et al., 2000). The object of the Phase V investigation at Parcel E-2 was to demonstrate whether residual radioactivity on the surface met the predetermined release criterion as summarized below.

- ^{226}Ra: 1 picocurie per gram (pCi/g) greater than background not to exceed 2 pCi/g[5]
- ^{90}Sr: 10.8 pCi/g
- ^{137}Cs: 0.13 pCi/g[6]
- ^{60}Co: 0.060 pCi/g

These release criteria were considered equivalent to EPA preliminary remediation goals (PRGs) for outdoor worker exposure to soil, based on agreements with EPA. For ^{226}Ra and ^{137}Cs, the outdoor worker release criteria are identical to the release criteria for future residents. In contrast, the outdoor worker release criterion for ^{90}Sr (10.8 pCi/g) is greater than the residential release criterion (0.331 pCi/g). Similarly, the outdoor worker release criterion for ^{60}Co (0.0602 pCi/g) is greater than the residential release criterion (0.0361 pCi/g).

The investigation area was divided into 73 Class 1 survey units measuring 40 by 50 meters (2,000 square meters, or 21,528 square feet) each. Each survey unit was assigned an alphabetic designation. Sixteen systematic sample locations were established in each grid approximately 11 meters apart. Figure 5 provides a layout of the survey units and the systematic sample locations. Reference (background) readings consisted of 16 1-minute static gamma readings taken on the hillside of Parcel A and 16 samples collected at various areas within Parcels B, C, D, and E.

[5] The ^{226}Ra release criterion was 5 pCi/g when the Phase V investigation was started but was subsequently reduced to 1 pCi/g above background; the uncertainty related to this change in criterion is discussed in Section 7.3.

[6] The ^{137}Cs release criterion applied to this survey when conducted in 2002 is slightly higher than the one used today (0.113 pCi/g); however, this change does not directly impact the results of this survey.

The Phase V investigation consisted of the following steps:

- Gamma scans of 100 percent of the surface area
- Sixteen systematic static gamma measurements in each survey unit
- Biased static measurements in areas where high gamma readings were measured
- Exposure rate measurements from the systematic static measurement locations
- Collection of soil samples at static and biased measurement locations
- Analysis of the soil samples by gamma spectroscopy at the on-site laboratory to quantify activity levels of a suite of 17 radionuclides, including ^{137}Cs and ^{226}Ra

A total of 1,168 systematic and 24 biased soil samples were collected during the Phase V investigation. Gamma scan measurements typically ranged from 4,500 to 8,000 cpm, with occasional scan measurements identified as being in excess of 10,000 cpm. Sample results identified residual radioactivity exceeding the release criteria for ^{137}Cs and ^{226}Ra in each survey unit. The elevated levels appeared to be consistent over the surface of the area, including the landfill cap, and there is a direct correlation between gamma static readings and gamma spectroscopy results. Results for samples from the reference areas indicated mean background activity level of 0.049 pCi/g for ^{137}Cs and 0.82 pCi/g for ^{226}Ra. These background activity levels are consistent with the background activity levels used for the interim removal actions at Parcels E and E-2 (TtECI, 2007a, 2007b, and 2007c). The analytical results from the systematic and biased soil samples are provided in Table A-2 of Appendix A, and the complete laboratory reports for the Phase V investigation are provided as an attachment to Appendix A. Figures 6 and 7 show the sample locations across Parcel E-2 where ^{226}Ra and ^{137}Cs exceeded the release criteria (1.82 pCi/g for ^{226}Ra and 0.113 pCi/g for ^{137}Cs; as stated previously, these release criteria are identical for outdoor worker and residential exposure scenarios). Figure 8 shows the sample locations where ^{60}Co exceeded the residential release criterion (0.0361 pCi/g; the outdoor worker release criterion is 0.0602 pCi/g). Only the Phase V survey units in the vicinity of the Experimental Ship-Shielding Area are presented on Figure 8, because ^{60}Co was the only ROC in this area of Parcel E-2.

Based on the sample results, every survey unit had activity levels of ^{226}Ra exceeding the release criterion and 46 of the survey units had activity levels of ^{137}Cs exceeding the release criterion. All of the eight survey units within the vicinity of the Experimental Ship-Shielding Area had activity levels of ^{60}Co exceeding the residential release criterion; however, only three of the eight survey units had activity levels of ^{60}Co exceeding the outdoor worker release criterion. Ten percent of the samples were sent to an off-site laboratory for quality assurance and ^{90}Sr analysis because the on-site laboratory did not analyze directly for ^{90}Sr. Results from the quality assurance laboratory were within the range of results from the on-site laboratory (based on a normal distribution of results). The average ratio of ^{90}Sr to ^{137}Cs results

19	Revised the remediation goal for ^{60}Co	Section 2.3.6	Final Action Memorandum, Time-Critical Removal Action for the Experimental Ship-Shielding Range, Parcel E-2, Hunters Point Naval Shipyard, San Francisco, California. Navy. May 2012. Appendix C, pages 1 through 3. Record No. 4417.

Appendix C

SUBJECT: Release Criterion for Cobalt-60 at Parcel E-2, Hunters Point Naval Shipyard, San Francisco, California, May 21, 2012

SUMMARY

The purpose of this document is to provide the basis for the revised radiological volumetric release criterion for cobalt-60 (^{60}Co) at Experimental Ship Shielding Range, Parcel E-2, Hunters Point Naval Shipyard (HPNS). The previous ^{60}Co release criterion was 0.0361 picocurie/gram (pCi/g).

A revised release criterion is provided to support efficient laboratory gamma spectroscopy analysis of soil samples. This revised release criterion maintains morbidity risks within the U.S. Environmental Protection Agency (EPA) defined acceptable range and permits an exposure level that does not increase the risk of cancer from a potential exposure to ^{60}Co.

The calculated revised release criterion for ^{60}Co is 0.252 pCi/g.

This calculation is based on a revised release criterion, which ensures that regulatory guidance is maintained for the following reasons:

- Residual radioactivity within the Experimental Ship Shielding Range is reduced and/or verified to be at levels that are as low as reasonable achievable
- Residual radioactivity that is distinguishable from background radiation results in a total effective dose equivalent that does not exceed 5 millirem per year (mrem/yr)

This calculation method utilizes a maximum dose rate of 6.624 mrem/yr per pCi/g of ^{60}Co to a resident farmer, which is a conservative scenario considering the proposed use for the area is wetland/open space. The basis and calculation methods are described below.

BASIS FOR COBALT-60 RELEASE CRITERION

The revised release criterion was calculated assuming a maximum allowed dose rate of 5 mrem/yr to hypothetical future land user. Selecting a resident farmer as the land user for a future scenario is a conservative measure since the proposed use for the area is wetland/open space.

The ^{60}Co is assumed to be uniformly distributed in the top 0.1524 meters (6 inches) of soil. The maximum dose occurs at the first year post closure. At every year post closure greater than 99 percent of the dose is from the external exposure pathways. The dose was calculated using the RESRAD code version 6.5 (Yu et al., 2001). RESRAD input included the following:

Attachment 1 lists the RESRAD input parameter values, units, and the reference for input parameter values that are not RESRAD default values. In addition, parameter input values listed in Attachment 1 that are not RESRAD default values have a yellow-shaded background. Attachment 2 lists all RESRAD input and output values for the risk calculation.

Based on the risk to concentration calculation methodology in Federal Guidance Report (FGR) No. 13, Health Risk from Low-Level Environmental Exposure to Radionuclides (EPA, 1998), a ^{60}Co concentration of 0.252 pCi/g results in a lifetime morbidity increase of 1.0 E-5. The EPA has stated that the acceptable range for morbidity risk is 1.0 E-4 to 1.0 E-6 (2000). The morbidity calculations are listed in Attachment 2.

The release criterion for ^{60}Co at the HPNS Radiological Screening Yard is 0.252 pCi/g. This concentration is conservative for the following assumptions:

- The land use scenario is a resident farmer. This land use is not anticipated but the calculated dose to the resident farmer will be a conservative upper bound to any realistic future land use
- Risk coefficients in FGR 13 are based on a linear relationship between dose and risk and are extrapolated from high-dose/high dose rate data under the assumption that there is no threshold. Studies of human populations exposed to low doses are inadequate to demonstrate any increase in risk
- Committee on Interagency Radiation Research and Policy Coordination (CIRRPC) states there is scientific uncertainty about cancer risk in the low-dose region and the possibility of no risk cannot be excluded (CIRRPC, 1992).

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presents the dose and risk estimates for all the survey units on the site, using the ratiometric approach. The dose and risk calculations, detailing the contribution from each ROC and each individual exposure pathway, are presented in Attachment B1.

To estimate the incremental risk from impacted soil areas, background concentrations of the ROCs were subtracted from the calculated 95 UCL values. As indicated in Section B4, sample results from the reference areas indicated mean background levels of 0.049 pCi/g for ^{137}Cs, 0.82 pCi/g for ^{226}Ra, and 0.18 pCi/g for ^{90}Sr. To estimate the total radiological risk, the calculated 95 UCL values were used as the EPC, without subtracting the background values. Background values were not calculated for ^{60}Co; therefore, the incremental radiological risk is the same as the total radiological risk.

Table B-7 presents the combined nonradiological and radiological risk at the three primary study areas at Parcel E-2 (Landfill Area, Panhandle Area, and East Adjacent Area; these study areas are impacted by both radioactive and nonradioactive chemicals). The nonradiological and radiological risk presented in Table B-7 represents the maximum risk associated with an exposure area within the Landfill Area, Panhandle Area, and East Adjacent Area. Since the exposure areas and associated grids used in the nonradiological and radiological risk analyses were different, the grids with the maximum nonradiological and radiological risk may not necessarily be collocated. Accordingly, the total risk presented in Table B-7 is an upper-bound estimate of risk.

The combined risk from the residential exposure scenario is not included in Table B-7 because this exposure scenario was not evaluated in the RI/FS. The combined risk from the Shoreline Area was not included in Table B-7 because limited soil samples were collected from the Shoreline Area and the resulting data were inadequate to estimate potential radiological risks.

B5.2.1. Critical Exposure Scenario Evaluation

An evaluation was performed to identify the critical exposure scenario based on the exposure scenarios identified in Section B2. The critical exposure scenario results presented in Table B-8 represent the range of radiological risks estimated for each receptor. Modeling results indicated that the residential exposure scenario is the critical exposure scenario (Table B-8). As indicated in Section B2, the residential exposure scenario is not anticipated in the future at Parcel E-2; however, the residential exposure scenario was evaluated because it represents the highest potential for exposure and resulting radiological risk.

An evaluation was performed to identify the critical exposure pathway based on the pathways (external radiation, soil ingestion, and inhalation) identified in Section B3. Evaluation results are shown in Table B-8. The critical exposure pathway results presented in Table B-8 are based upon the range of radiological risks estimated for each receptor. As indicated in Table B-8, external exposure accounts for over 99 percent of all radiological risks, which is nearly all of the radiological risk for each receptor.

presents the dose and risk estimates for all the survey units on the site, using the ratiometric approach. The dose and risk calculations, detailing the contribution from each ROC and each individual exposure pathway, are presented in Attachment B1.

To estimate the incremental risk from impacted soil areas, background concentrations of the ROCs were subtracted from the calculated 95 UCL values. As indicated in Section B4, sample results from the reference areas indicated mean background levels of 0.049 pCi/g for ^{137}Cs, 0.82 pCi/g for ^{226}Ra, and 0.18 pCi/g for ^{90}Sr. To estimate the total radiological risk, the calculated 95 UCL values were used as the EPC, without subtracting the background values. Background values were not calculated for ^{60}Co; therefore, the incremental radiological risk is the same as the total radiological risk.

Table B-7 presents the combined nonradiological and radiological risk at the three primary study areas at Parcel E-2 (Landfill Area, Panhandle Area, and East Adjacent Area; these study areas are impacted by both radioactive and nonradioactive chemicals). The nonradiological and radiological risk presented in Table B-7 represents the maximum risk associated with an exposure area within the Landfill Area, Panhandle Area, and East Adjacent Area. Since the exposure areas and associated grids used in the nonradiological and radiological risk analyses were different, the grids with the maximum nonradiological and radiological risk may not necessarily be collocated. Accordingly, the total risk presented in Table B-7 is an upper-bound estimate of risk.

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An evaluation was performed to identify the critical exposure pathway based on the pathways (external radiation, soil ingestion, and inhalation) identified in Section B3. Evaluation results are shown in Table B-8. The critical exposure pathway results presented in Table B-8 are based upon the range of radiological risks estimated for each receptor. As indicated in Table B-8, external exposure accounts for over 99 percent of all radiological risks, which is nearly all of the radiological risk for each receptor.

$$Risk_{UCL} = \frac{Risk_{RG}}{RG} \times UCL$$

where:

- RG = remediation goal (in picocuries per gram, pCi/g; as noted below, both outdoor worker and residential RGs are used)
- $Risk_{RG}$ = human health risk for the individual ROCs at the proposed RGs[11] (as noted below both outdoor worker and residential RGs are used)
- $Risk_{UCL}$ = human health risk, specific to the given exposure scenario (i.e., recreational, residential, or construction worker), associated with upper confidence limit of mean (in pCi/g)
- UCL = 95th percentile upper confidence limit of mean (in pCi/g) in an individual Phase V survey unit (see Table 2)

After dose and risk were estimated for the four ROCs (^{60}Co, ^{137}Cs, ^{226}Ra, and ^{90}Sr) at the proposed RGs, dose and risk estimates were back calculated for the survey units based upon the ratio of the measured activity level and the associated risk. This approach greatly reduces the time and effort required to estimate dose and risk for a large number of survey units, with a precision comparable to that of using RESRAD for each survey unit.

To estimate the incremental radiological risk from impacted soil areas, background activity levels of the ROCs were subtracted from the calculated 95 UCL values. As indicated in Section 3.1.6, sample results from the reference areas indicated mean background activity levels of 0.049 pCi/g for ^{137}Cs, 0.82 pCi/g for ^{226}Ra, and 0.18 pCi/g for ^{90}Sr. Background activity levels were not calculated for ^{60}Co. A mean background activity level of 0.18 was calculated for ^{90}Sr based upon the average ratio of ^{90}Sr to ^{137}Cs results from the off-site laboratory; this value was used to calculate the EPCs for ^{90}Sr. To estimate the total radiological risk, the calculated 95 UCL values were used as the exposure point concentration, without subtracting the background values.

RESRAD incremental risk estimates for radionuclides exceed 1E-05 for future recreational users and exceed 1E-06 for future construction workers. In addition, RESRAD incremental risk estimates for a residential exposure scenario exceed 1E-04; as stated in Section 7.1, the residential exposure scenario is not associated with the reasonably anticipated reuse but provides an upper-bound estimation of risk from exposure to ROCs at the parcel. These results indicate that concentrations of radioactive chemicals in soil pose a potential unacceptable risk to future site users and remedial alternatives should be evaluated to address these potential risks. Although the extent of radioactive contamination in subsurface soil has not been defined, this radiological addendum conservatively assumes, consistent with the findings of the HRA (Table 3; NAVSEA, 2004), that potential radioactive chemicals (specifically, ^{60}Co, ^{137}Cs, ^{226}Ra, and

[11] The residential RG is used to estimate risk for the recreational and residential exposure scenarios, and the outdoor worker RG is used to estimate risk for the construction worker exposure scenario.

^{90}Sr) may be present in subsurface soil at Parcel E-2 and will therefore require analysis of remedial alternatives. In addition, the RI/FS Report concluded that subsurface soil throughout Parcel E-2 contains nonradioactive chemicals that require analysis of remedial alternatives. As a result, the remedial alternatives evaluated in the RI/FS Report and this radiological addendum address the potential radioactive and nonradioactive chemicals in subsurface soil at Parcel E-2.

The highest total and incremental risk results for the primary Parcel E-2 study areas (Landfill Area, Panhandle Area, and East Adjacent Area) are presented in Table 7. As noted in Table 7, RESRAD incremental risk estimates at Phase V survey units ACH and AKL were affected by anomalous biased samples with reported activity levels that were two to three orders of magnitude greater than the activity levels reported in the 16 systematic samples collected within the same survey unit. The biased soil samples at survey units ACH and AKL were collocated with radioactive point source anomalies that were subsequently removed. Therefore, the Navy believes that the RESRAD risk estimates using only the systematic samples collected within survey units ACH and AKL (exclusive of the biased sample results) are most representative of current site conditions. However, the anomalous biased sample results were retained in separate RESRAD risk estimates for survey units ACH and AKL to conservatively account for the possibility of residual contamination left at the individual survey unit.

7.3. COMBINED RADIOLOGICAL AND NONRADIOLOGICAL RISK

Estimates of the lifetime risk of cancer to exposed individuals resulting from radiological and nonradiological risk assessments may be summed to determine the overall potential human health hazard associated with a site (EPA, 1989). To combine the nonradiological risk and radiological risk, the same approach used in the Parcel E-2 RI/FS to calculate nonradiological risk must be taken; namely, calculating total risk from ROCs inclusive of background and calculating incremental risk from the ROCs present at activity levels that do not include background.

Table 7 presents the combined nonradiological and radiological risk at the primary Parcel E-2 study areas (Landfill Area, Panhandle Area, and East Adjacent Area). The nonradiological and radiological risk presented in Table 7 represents the maximum risk associated with an exposure area within the Landfill Area, Panhandle Area, and East Adjacent Area. Since the exposure areas and associated grids used in the nonradiological and radiological risk analyses were different, the grids with the maximum nonradiological and radiological risk may not necessarily be collocated. Accordingly, the total risk presented in Table 7 is an upper-bound estimate of risk. The combined risk from the Shoreline Area was not included in Table 7 because limited soil samples were collected from the Shoreline Area and the resulting data were inadequate to estimate potential radiological risks; however, as discussed in Section 3.1.5, gamma scans performed along the shoreline identified potential anomalies that require analysis of remedial alternatives in the FS.

Additionally, radiological risk was calculated based on estimated concentrations of radiological contamination at radiologically impacted sites, using remediation goals for each radionuclide of concern. Actual calculated risk will be based on field measurements following receipt of final status survey results for each impacted site. **Radiological risks**(19) for soil and building structures are greater than 10^{-6} at Redevelopment Blocks 30A, 38, and 39 (see Table 2). Total and incremental risks were also calculated for radionuclides with Radium-226, the only naturally occurring radionuclide that affected the incremental risk calculation. However, the background concentration of Radium-226 in building materials was assumed to be zero.

Potential risks were primarily based on exposure to metals (arsenic, lead, and manganese) and PAHs in soil, VOC vapors and several metals (chromium VI and nickel) from groundwater in the A-aquifer, and radionuclides in structures (such as buildings) and soil. **Combined chemical and radiological risk**(20) was also summed to determine the overall potential risk to human health associated with a site.

The HHRA specifies the **assumptions and uncertainties**(21) inherent in the risk assessment process due to the number of samples collected or their location, the literature-based exposure and toxicity values used to calculate risk, and risk characterization across multiple media and exposure pathways. The effects of uncertainties are overestimation or underestimation of the actual cancer risk or HI. In general, the risk assessment process is based on the use of conservative (health-protective) assumptions that when combined, are intended to overestimate the actual risk.

2.5.2 Ecological Risk Assessment

As previously stated, the Navy concluded during the RI that limited viable habitat is available for terrestrial wildlife at Parcel D because most of the site is covered with pavement. Specifically, the RI concludes that "Parcels C and D are almost entirely paved except for small pockets of vegetation which are not considered suitable habitat for animal life." In addition, the shoreline habitat is not a concern for Parcel G because of its inland location. Therefore, ecological risk associated with exposure to soil was not evaluated further in the Revised FS Report.

The Navy completed a screening evaluation of **surface water quality**(22) to assess potential exposure by aquatic wildlife to groundwater as it interacts with the surface water of San Francisco Bay. Results of the screening evaluation indicated two metals (**chromium VI and nickel**(23)) in groundwater may pose a potential risk to aquatic wildlife. However, the current areas within Parcel G where chromium VI and nickel are present are not in close proximity to the nearest discharge point on the Bay. Groundwater monitoring data indicated metals migrate at a much slower rate than groundwater flows; thus, discharge of metals to the Bay is not imminent.

Chemicals present in both the A-aquifer and the B-aquifer groundwater at Parcel G were evaluated to assess potential **environmental impacts to the Bay**(24). This evaluation was completed as part of the derivation of **trigger levels**(25) for chemicals that present a potential impact to the Bay. Based on the evaluation results, chromium VI and nickel in the A-aquifer were identified as COCs that originated in Parcel G.

Table 5. Remediation Goals for Radionuclides

Radionuclide	Surfaces (dpm/100 cm^2)		Soil (pCi/g)		Water (pCi/L)
	Equipment Waste [a]	Structures[b]	Construction Worker	Resident[d]	
Cesium-137	5,000	5,000	0.113	0.113	119
Cobalt-60	5,000	5,000	0.0602	0.0361	100
Plutonium-239	100	100	14	2.59	15
Radium-226	100	100	1[c]	1[c]	5
Strontium-90	1,000	1,000	10.8	0.331	8
Thorium-232	1,000	36.5	19	1.69	15
Hydrogen-3	5,000	5,000	4.23	2.28	20,000
Uranium-235 + daughters	5,000	488	0.398	0.195	30

Notes:

a Limits for removable surface activity are 20 percent of these values.

b Remediation goals are consistent with those issued in the Radiological TCRA Action Memo. Remediation goals meet the 25 millirem per year residual dose level consistent with 10 CFR Section 20.1402. Furthermore, for most radionuclides of concern, goals meet the 15 millirem per year residual dose level consistent with the 1997 EPA OSWER Directive (OSWER No. 9200.4-18). Of exception is the goal for Thorium-232 goal which due to detection limit technical limitations, corresponds to a dose of 25 mrem/yr.

c Goal is 1 pCi/g above background per agreement with EPA.

d All radiologically impacted soils in this parcel will be remediated according to Residential Remediation Goals.

ARAR Applicable or relevant and appropriate requirements
CFR Code of Federal Regulations
dpm/100cm^2 Disintegration per minute per one hundred square centimeters
EPA U.S. Environmental Protection Agency
millirem One thousandth of a rem (10^{-3})
mrem/yr Millirem per year
NRC Nuclear Regulatory Commission
OSWER Office of Solid Waste and Emergency Response
pCi/g Picocurie per gram
pCi/L Picocurie per liter
TCRA Time-Critical Removal Action

2.8.1 Description of Remedial Alternatives

Table 6 provides the major components, details, and cost of each remedial alternative identified for soil, groundwater, and radiologically impacted sites.

2.8.2 Comparative Analysis of Alternatives

A comparative analysis of alternatives with respect to the **nine evaluation criteria**$_{(33)}$ was completed and is provided below. Table 7 depicts a relative ranking of the alternatives.